ASIC Implementation Challenges for Next Generation Access Networks

P. Ossieur[1], G. Coudyzer[1], D. Kelly[2], X. Yin[1], P.D. Townsend[2] and J. Bauwelinck[1]
[1]*Ghent University - imec, IDLab, Department of Information Technology, Belgium*
[2]*Photonic Systems Group, Tyndall National Institute and University College Cork, Ireland*
peter.ossieur@imec.be

Abstract: We consider challenges associated with increasing bitrates >10Gb/s for next-generation access networks. We explain how burst-mode electronic dispersion compensation (BM-EDC) is attractive for the upstream, and show examples of the required linear burst-mode receiver.
OCIS codes: (000.0000) General; (000.0000) General [8-pt. type] For codes, see http://www.osapublishing.org/submit/ocis/

1. Introduction

With 10Gb/s capable optical access networks now being actively deployed, industry is considering different options to scale to 25Gb/s, 50Gb/s and 100Gb/s rates. The IEEE 802.3ca 100G EPON (Ethernet Passive Optical Network) Task Force is considering different options, FSAN has revealed its new roadmap (see Fig.1) and the ITU-T Study Group 15 has readied a supplement for >10G PON [1,2].

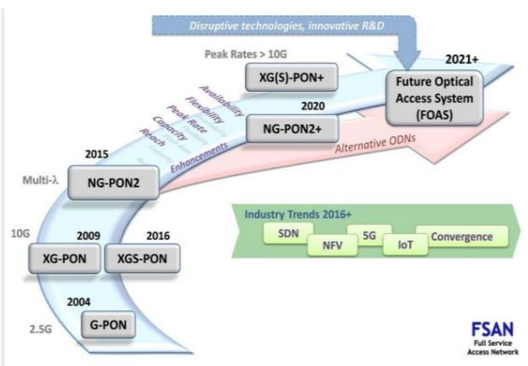

Fig. 1 – FSAN Standards Roadmap 2.0.

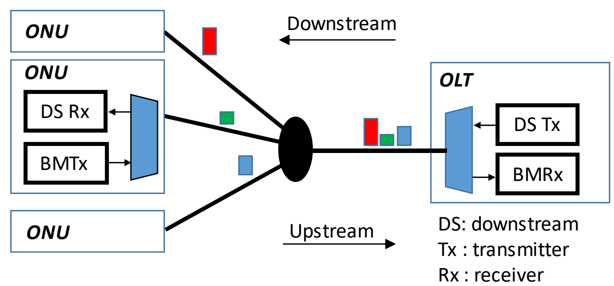

Fig. 2 –Simplified view on a Passive Optical Network.

Fig. 2 gives a simplified overview of a passive optical network (PON). A number (typically 16 up to 64) of optical network units (ONUs) located at the user's premises are connected to an optical line termination (OLT) using a tree-like fiber distribution network. In the downstream direction (from OLT to ONUs), time division multiplexing (TDM) is used to share the fiber plant between the ONUs. The signal arriving at the ONUs is a continuous stream of bits: conventional optical transceivers can handle this downstream traffic. In the upstream direction, the transmitters in the different ONUs share the same fiber link. Time division multiple access (TDMA) in which each ONU is allocated non-overlapping timeslots is typically used today to share the fiber plant. This requires burst-mode transmitters at the ONU, which can quickly turn on and off their optical output. The upstream signal which arrives at the OLT now consists of a quick succession of bursts, whose amplitude and phase (with respect to the OLT clock) can vary significantly from burst to burst. Over 20dB (optical power) dynamic range between bursts and unknown phase are typical requirements. A so-called burst-mode receiver (BMRx) is now required to recover the transmitted bits from such signal. A BMRx needs to quickly recover the amplitude of incoming bursts, and set its gain and decision threshold (to slice the signal) during a short preamble at the start of each burst. Many BMRx's capable of operation up to 10Gb/s (non return to zero modulation) have been demonstrated over the past decade, see e.g. [3,4].

2. Linear burst-mode receiver

Due to the relatively short reach (20km), careful selection of transmission wavelength (for example 1270nm) and availability of high quality (low chirp) optics at low costs, the impact of chromatic dispersion in the upstream direction could be kept small at 10Gb/s. However, when considering options to scale to 25Gb/s or moving the upstream transmission wavelength to the C-band this changes drastically. When using direct modulation of the ONU laser, chromatic dispersion may now result in significant transmission penalties. External modulation may help but requires optics that are more expensive. To keep the cost sufficiently low, transceiver manufacturers may consider re-using 10G optics for 25G capable links [5]. Multi-level (e.g. 4-ary pulse amplitude modulation PAM-4) or duobinary modulation formats have been considered for such options [6,7]. In addition, some form of dispersion compensation or more in general compensation of signal impairments in the full link (transmitter, fiber, receiver) will become important for the upstream channel. Although chromatic dispersion can be compensated in the optical domain using e.g. dispersion compensating fiber (DCF) or fiber bragg gratings, such components are expensive and bulky and hence difficult to deploy in OLTs. In addition, the amount of chromatic dispersion may vary from one ONU to another, and hence adaptive chromatic dispersion compensation is then necessary. A natural candidate is then burst-mode electronic dispersion compensation (BM-EDC), first considered for PONs in [8] and further explored in [9,10].

For existing 10G upstream links, a so-called limiting BMRx is typically used: the input signal is sliced using a comparator (or equivalently using a limiting amplifier) to make a distinction between digital 1s and 0s. However, EDC requires that the receiver front-end preserves the signal shape, and hence a linear BMRx (LBMRx) is now required. Such LBMRx amplifies the incoming bursts linearly such that at its output, all bursts have equal amplitude (e.g. peak or average amplitude). Gain equalization must be done quickly (within a few tens of nanoseconds) at the start of each burst. Maintaining linearity inside such LBMRx requires significantly higher design effort, with focus on keeping low total harmonic distortion (THD, <5% being a typical requirement) or sufficiently large 1dB compression point. Low-noise operation is critical to support the required optical budgets. A first such LBMRx was demonstrated in [11]; another example can be found in [12] featuring an avalanche photodiode (APD) to improve sensitivity. Note that when considering advanced modulation formats for the upstream, some of these (e.g. PAM-4, 16-QAM) will also require a linear BMRx.

3. Requirements for burst-mode electronic dispersion compensation

Several options can be considered to implement BM-EDC, ranging from simple continuous-time linear equalization (CTLE) using analog filters, over multi-tap feedforward equalizers/decision feedback equalizers (FFE/DFE), up until e.g. maximum likelihood sequence estimation (MLSE). The latter typically requires analog-to-digital conversion (ADC) of the LBMRx output and digital signal processing, which can be expensive and power-hungry. The option of a mixed signal FFE/DFE implementation provides an optimum trade-off between performance on one hand and low-cost on the other hand. An important requirement is the capability of rapid settling of the FFE/DFE tap coefficients. Experiments based on off-line processing detailed in [10] suggest that FFE/DFE tap adaptation is possible using a gear-shifted least mean squares algorithm (LMS) with less than 250 training bits, which would be embedded in a short preamble at the start of each burst.

4. Conclusion

Options for the burst-mode receiver electronics in the optical line termination for 25G capable PONs have been provided. Linear burst-mode receivers and associated burst-mode capable electronic dispersion compensation are excellent candidates to sustain such rates for next generation access networks.

Acknowledgment. G. Coudyzer thanks the Special Research Fund (BOF) from Ghent University for scholarship support, funding from Science Foundation Ireland (grants 12/RC/2276 and 12/IA/1270) is gratefully acknowledged.

5. References

[1] IEEE P802.3ca 100G-EPON Task Force, Physical Layer Specifications and Management Parameters for 25Gb/s, 50Gb/s and 100Gb/s Passive Optical Networks, [online] www.ieee802.org/3/ca

[2] "Supplement to ITU-T G-series recommendations PON transmission technologies above 10Gb/s per wavelength", ITU-T SG-15, 2018.

[3] P. Ossieur, et.al., "A 10 Gb/s burst-mode receiver with automatic reset generation and burst detection for extended reach PONs", in Proceedings Optical Fiber Conference (OFC'2009), paper OWH3, March 2009.

[4] X. Yin et.al., "Experiments on 10Gb/s fast settling high sensitivity burst-mode receiver with on-chip auto-reset for 10G-GPON", in Proceedings Optical Fiber Conference (OFC'2012), paper NTu1J.4, March 2012.

[5] A. Stark and T. Detwiller, "Equalization strategies for 25G PON", in Proc. Optical Fiber Conference (OFC'2017), paper Th2A.24, 2017.

[6] M. D. Santa, et.al., "25Gb/s PAM4 Burst-Mode System for Upstream Transmission in Passive Optical Networks", *Optical Fiber Conference* (OFC'2017), 2017.

[7] X. Yin et.al., "25Gb/s 3-level burst-mode receiver for high serial rate TDM-PONs", in Proc. Optical Fiber Conference (OFC'2015), Paper. Th4H.2, March 2015.

[8] P. Ossieur et.al., "Burst-mode electronic equalization for 10Gb/s passive optical networks, " *IEEE Photon. Technol. Lett.*, vol. 20, pp. 1706-1708, Oct. 2008.

[9] S. Porto, et.al., "Demonstration of 10Gb/s burst-mode transmission using a linear burst-mode receiver and burst-mode electronic equalization", *Optical Fiber Conference* (OFC'2014), paper M3I.5, March 2014.

[10] S. Porto, et.al., "Demonstration of 10Gb/s burst-mode transmission using a linear burst-mode receiver and burst-mode electronic equalization", *Journal of Optical Communications and Networking*, vol. 7, Jan. 2015.

[11] P. Ossieur et.al., "A 10G linear burst-mode receiver supporting electronic dispersion compensation for extended-reach optical links, " ECOC'2011, Postdeadline Paper Th.13.B.4, Sept. 2011.

[12] X. Yin. "A 10Gb/s APD-based linear burst-mode receiver with 31dB dynamic range for reach-extended PON systems", ECOC'2012, Paper Tu.1.D.5, 2012.